DOCUMENT RESUME

ED 480 793 SE 068 034

AUTHOR	Rushton, Erik; Ryan, Emily; Swift, Charles
TITLE	An Introduction to Loads Acting on Structures. Grades 6-8.
INSTITUTION	Tufts Univ., Medford, MA.
PUB DATE	2001-00-00
NOTE	16p.; Produced by the Office for Technology and Industry Collaboration. For other activities in series, see SE 068 011-041.
AVAILABLE FROM	Web site: www.prek-12engineering.org/activities/ .
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	Engineering; *Experiential Learning; *Force; Hands on Science; Laboratory Experiments; Middle Schools; Physics; Science Activities; Science Education; Science Instruction; Science Process Skills; *Scientific Concepts

ABSTRACT

In this activity, students conduct several simple lab activities to learn about the five fundamental load types that can act on structures: tension, compression, shear, bending, and torsion. In Part One, students play the role of molecules in a beam subject to various loading schemes. In Part Two, students break foam insulation blocks by applying these five fundamental load types. Each type of fracture pattern (break in the material) is carefully studied and drawings of them are made in order to learn the telltale marks of failure due to each fundamental load type. This activity requires a 100-minute time period for completion. (Author/NB)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 480 793

Activity: **AN INTRODUCTION TO LOADS ACTING ON STRUCTURES**

GRADE LEVELS: 6-8

SUMMARY:

Students will conduct several simple lab activities to learn about the five fundamental load types that can act on structures: tension, compression, shear, bending, and torsion. In Part One, students will play the role of molecules in a beam subject to various loading schemes. In Part Two, students break foam insulation blocks by applying these five fundamental load types (tension, compression, shear, bending and torsion). Students will study carefully each type of fracture pattern (break in the material) and make drawings of the fracture patterns in their notes in order to learn the telltale marks of failure due to each fundamental load type.

LEVEL OF DIFFICULTY [1 = Least Difficult: 5 = Most Difficult]

4- difficult

TIME REQUIRED

100 minutes (2 class periods)

COST

$10 per class

STANDARDS:

Mass. Science & Technology / Engineering Grades 6-8 / Construction Technologies & Engineering Design

5.3 Explain how the forces of tension, compression, torsion, bending and shear affect the performance of bridges.

www.prek-12engineering.org
Copyright © 2001
All Rights Reserved

BEST COPY AVAILABLE

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

M. Newell

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, multiview drawings.

2.3 Describe and explain the purpose of a given prototype.

2.5 Explain how such design features as size, shape, weight, function and cost limitations (i.e., ergonomics) would affect the construction of a given prototype.

WHAT WILL THE STUDENTS LEARN?

The students will learn to identify the five fundamental loads: compression, tension, shear, bending and torsion.

What is meant by something being elastic and non-elastic

Molecules + bonds

BACKGROUND INFORMATION:

A lot of information is available in the directions

Each type of load has its own telltale marks which engineers use to identify the mode of failure (type of load causing failure) of a structure or its component parts. This is exactly what National Transportation Safety Board (NTSB) engineers do when you see them on the evening news talking about a crash investigation; they recover and analyze all the parts of the aircraft or train to determine what part(s) failed, how they failed, and why, in an effort to determine the cause of the crash.

"Fairly Fundamental Facts about Forces and Structures" Attached

Vocabulary

Fracture- A break, split, or crack in an object or a material.

Elastic- The ability of an object to return quickly to its original shape and size after being bent, stretched, or squashed.

Inelastic- The inability of an object to return quickly to its original shape and size after being bent, stretched, or squashed.

Resources:

http://www.pbs.org/wgbh/buildingbig/lab/forces.html

The five fundamental loads with animated drawing and real life examples.

http://library.thinkquest.org/10170/menuw.htm

Simulations and explanations about forces, momentum, etc

Copyright © 2001
All Rights Reserved

http://www.proteacher.com/cgi-bin/outsidesite.cgi?external=http://www.yesmag.bc.ca/focus/structures/structure_science.html&original=http://www.proteacher.com/110031.shtml&title=Why%20does%20it%20not%20fall%20down?

Tension and compression description and pictures

MATERIALS:

extruded foam insulation, 1" X 4' x 8' (should be enough for 6 groups out of one piece)

Exacto knife

black sharpie marker

ruler

magnifying glass (optional)

PREPARATION:

"Fairly Fundamental Facts about Forces and Structures", should be reproduced for each student and discussed as a class before or during the activity. Discussing each load in "Fairly Fundamental Facts about Forces and Structures", before performing the experiment, which analyzes that load, may be very helpful.

Cut the extruded foam insulation into strips 1"x 1" x 4'. Each team needs at least one full piece (1"x1"x4') and one 1/4 piece (1"x1"x1'). They will also need one-piece 1"x1"x2" for part 2b.

DIRECTIONS:

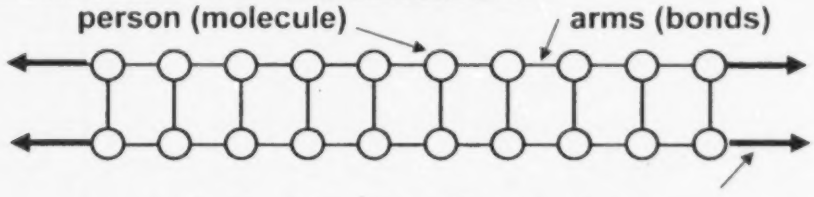
PART ONE: Modeling Loads on Structures Using "Human Molecules"

Each person will represent a molecule of steel inside a steel bar and their arms will represent the internal bonding forces, which hold molecules together (a molecule is the smallest piece of steel that can exist with the chemical and physical properties of steel – billions of molecules link together in lines to make a piece of steel).

Copyright © 2001
All Rights Reserved

1. Form two lines of ten people each, lining up side by side, facing each other (see diagram). These two lines represent a structural element. Each person must use his/her left hand to hold hands with the person whom they are facing in the other line. Each person should then lock his/her right arm around the arm of the person on his/her right. See Figure 1.

Figure One: Forces on Human Molecule



2. Four other students will act as an applied load. Position one student at each end of both lines, and have them pull with equal force (if possible). Have the students pay attention to what they are feeling while the molecules are being pushed and pulled. Next, form the same lines again, but have the four people applying the loads push equally on each line end. The job of the molecules is to try to maintain their original formation, like a solid non-elastic object.

Group Discussion:

What type of loads did you model? What did it feel like to be a molecule inside the material (note which arm took most of the load – left or right?)?

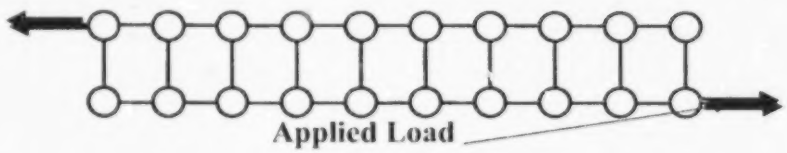
3. Now have the "applied load" students pull one line of molecules to the left, and the other line of molecules to the right (as shown in the Figure 2).

Group Discussion:

What type of load did you model this time? What did it feel like to be a molecule inside the material?

Copyright © 2001
All Rights Reserved

Figure Two: Human Molecule in Shear



PART TWO: Looking at Loads: Studying the Five Fundamental Loads and Their Effect on Materials.

1. From the pieces supplied to each group have them cut (10) 1" X 1" X 6" blocks of extruded foam insulation.

2. Instruct the students to do the tests included below; make drawings of each fracture, and record observations on appropriate data sheets:

2a. Tension

Have the students measure the length of the block, before breaking it. Two students should work together to pull on the block as straight as possible (from the ends) until it breaks. Put the two pieces back together and measure the change in length of the block. A slightly dished in fracture (break) that is characteristic of a tensile failure should be noted.

2b. Compression

A student should use a 2" high block of insulation foam and stand on the block or place a weight on it; try to keep the load perfectly vertical and stable. You should observe wrinkles on the outside of the material, as well as the bulging of the material, both of which are signs of a compressive failure. Next students should try the compression test again using a 6" long block. Because of its slender (long and thin) shape, it will fail by buckling.

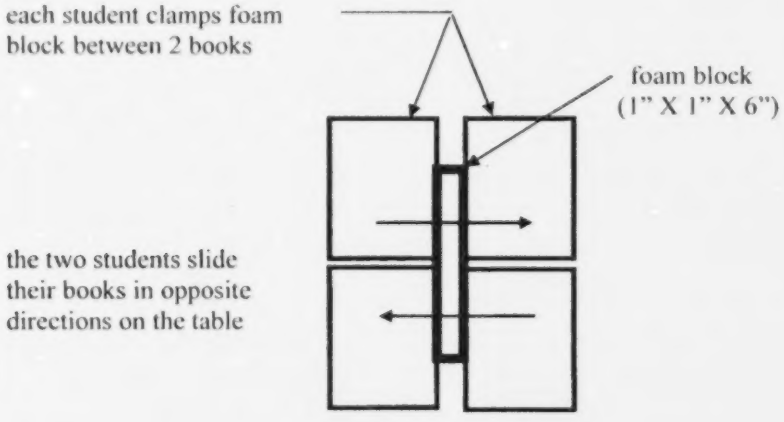
2c. Shear

Two students should use two textbooks each, as is shown in figure three, to demonstrate shear. When blocks are sheared apart as shown in Figure

Copyright © 2001
All Rights Reserved

3, a rough angular fracture will be observed (an uneven fracture with several planes of the material angled in different directions).

Figure Three: Conducting the Shear Experiment


each student clamps foam block between 2 books
foam block (1" X 1" X 6")
the two students slide their books in opposite directions on the table

2d. Bending

On each side of a block of insulation draw a 5" line down the middle and then slowly bend it until it breaks. As load is applied, notice that the lines form a bowed shape on the two sides of the beam (like a smile).

Group Discussion:

What happened to the lines on the top and bottom of the block? A bending moment makes a beam "smile", causing one side of the beam to be pulled apart (tension) and the opposite side to be pushed together (compression). While the load is applied, this should be observable. (A beam subjected to bending will actually fail in tension because materials have a lower tensile strength and a higher compressive strength.) On the side of the beam that

Copyright © 2001
All Rights Reserved

experiences tension, the same flat or slightly dished-in fracture seen in the tension test will be visible on the opposite side of the beam small wrinkles indicating compression and a bump in the fracture plane may be visible. Because of the combination of tensile, compressive, and shear stresses (internal forces) in the beam, the same clean break seen in pure tension is not likely to occur.

2e. Torsion

On each side of a block of insulation draw a 5" line down the middle and slowly twist the block about its center until it breaks. A twisting (torsional) moment causes angular rotation in a beam. This means that each slice of insulation (within a single plane of molecules) actually rotates slightly and the molecules are being sheared or slid apart. Beams or any structural member loaded solely in torsion, will experience a shear failure because torsion forces produce high internal shear stresses (sliding and ripping) between molecules and layers inside the material. You can tell it's a shear failure because of the rough, angular ripped-apart quality of the fracture.

INVESTIGATING QUESTIONS:

Describe the fundamental loads and the effect each load (of force) has on a structure or structural member (or component).

Give real life examples of tension, compression, shear, bending, and torsion.

REFERENCES:

Douglas Prime

Tufts University, Center for Engineering Educational Outreach

WORKSHEETS: (see links)

"Fairly Fundamental Facts about Forces"

Figures 1-3 for Loads Acting on Structures

Copyright © 2001
All Rights Reserved

SAMPLE RUBRIC:

This rubric is not in the same format as all of the others. Class participation, List and define the five fundamental loads (possible quiz)

Copyright © 2001
All Rights Reserved

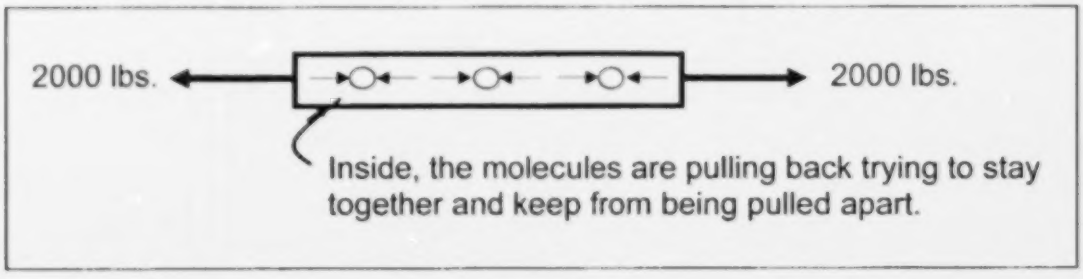
FAIRLY FUNDAMENTAL FACTS ABOUT FORCES & STRUCTURES

by Douglas Prime
Tufts University
Center for Engineering Educational Outreach

Everyone knows from experience that a **force** is a pushing or a pulling action which moves, or tries to move, an object. Engineers design **structures**, such as buildings, dams, planes and bicycle frames, to hold up weight and withstand forces that are placed on them. An engineers job is to first determine the **loads** or external forces that are acting on a structure. Whenever external forces are applied to a structure, **internal stresses** (internal forces) develop within the materials between materials that resist the outside forces and act to hold the structure together. Once an engineer knows what loads will be acting on a structure, she has to calculate the resulting internal stresses, and design each **structural member** (piece of the structure) so it is strong enough to carry the necessary loads without breaking (or coming close to breaking).

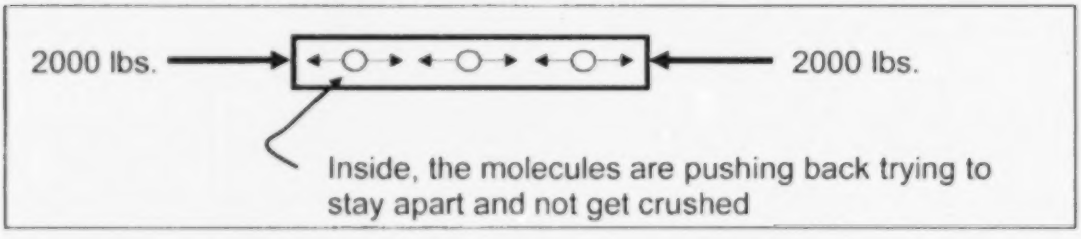
THE FIVE TYPES OF LOADS THAT CAN ACT ON A STRUCTURE ARE TENSION, COMPRESSION, SHEAR, BENDING AND TORSION

1) **Tension**: Two pulling forces directly opposing each other that stretch out an object and try to pull it apart (ex. pulling on a rope, a car towing another car with a chain – the rope and the chain are in tension or are "being subjected to a tensile load")



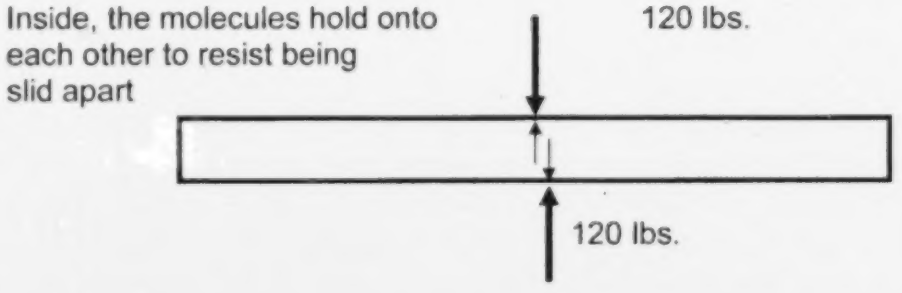
Copyright © 2001
All Rights Reserved

2) **Compression**: Two pushing forces directly opposing each other which squeeze an object and try to squash it (ex. Standing directly over a soda can, squeezing a piece of wood in a vise – both the can and the wood are in compression or are "being subjected to a compressive load").

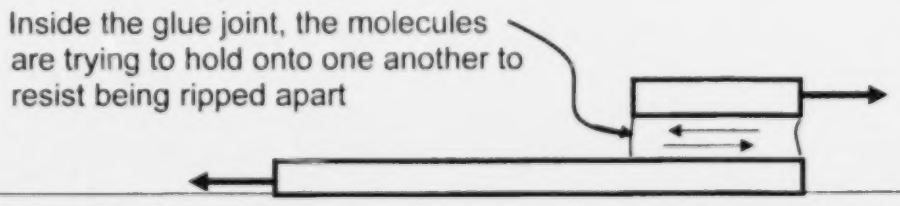


3) **Shear:** Two pushing or pulling forces acting close together but **not** directly opposing each other – a shearing load cuts or rips an object by **sliding its molecules apart sideways.**

ex. pruning shears cutting through a branch
paper cutter cutting paper
(the branch and the paper are "subjected to a shear loading")



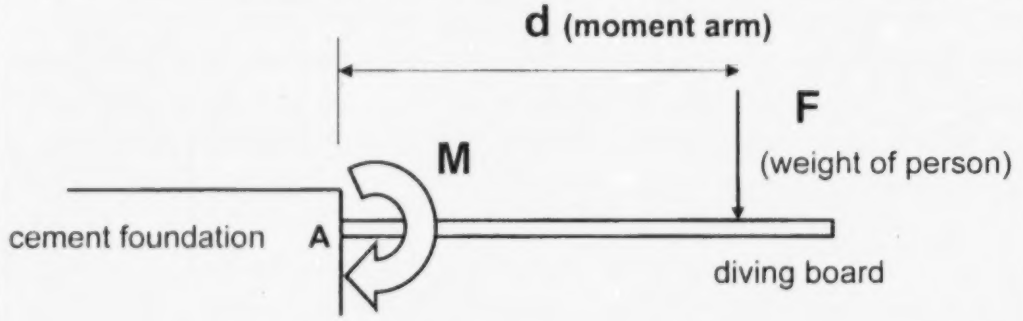
ex. pulling on two pieces of wood that have been glued together (the glue joint is "being subjected to a shear loading")



www.prek-12engineering.org
Copyright © 2001
All Rights Reserved

A Moment of A Force

Before you can understand the last two types of loads, you need to understand the idea of **a moment of a force**. A moment is a "bending force" caused by a force acting on an object at some distance from a fixed joint or point of interest. Consider the diving board shown below. The heavier the person, and the farther he walks out on the board, the greater the "turning force" which acts on the diving doard support.



The force (F) produces a moment or "turning force" (M) that tries to rotate the diving board around a fixed joint (A) – in this case the moment bends the diving board.

The stronger the force and the greater the distance at which it acts, the larger the moment or "turning force" it produced by the force.

A moment or "turning force" (M) is calculated by multiplying a force (F) by its moment arm (d) – the moment arm is the distance at which the force is applied, taken from the fixed joint:

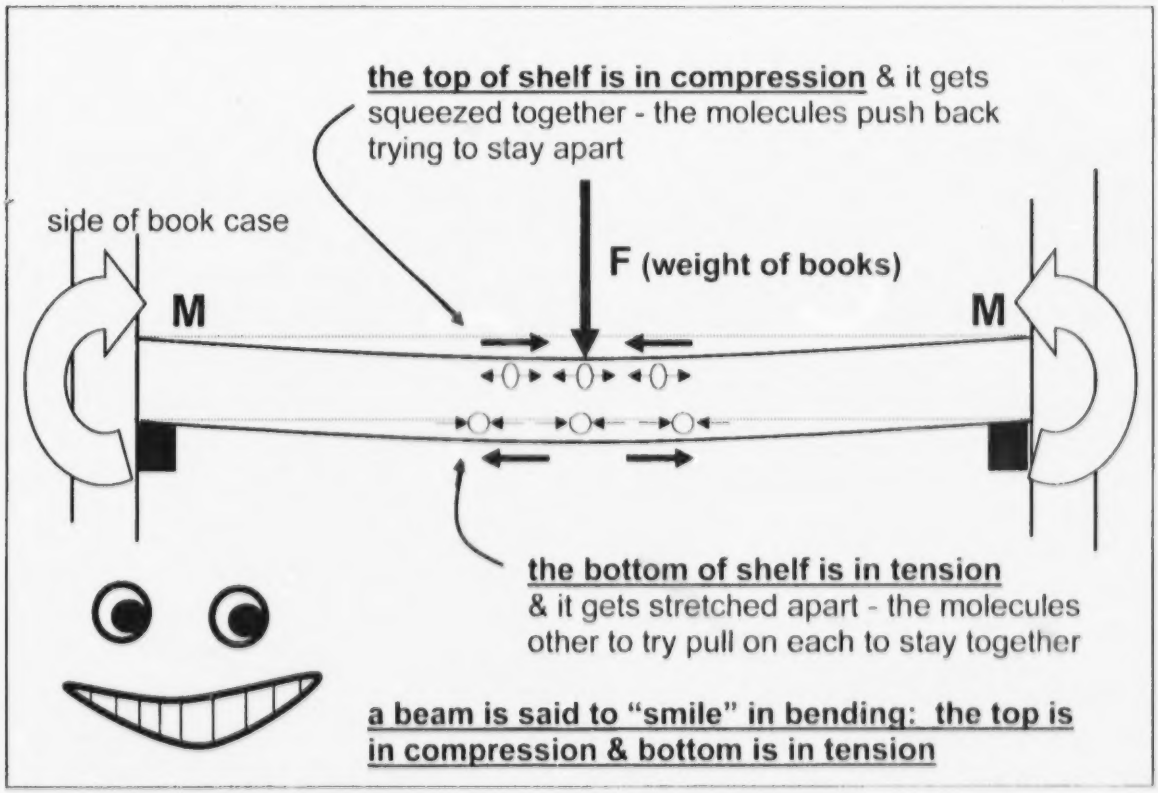
$$M = F \bullet d$$

(as long as the force acting on the object is perpendicular to the object)

Copyright © 2001
All Rights Reserved

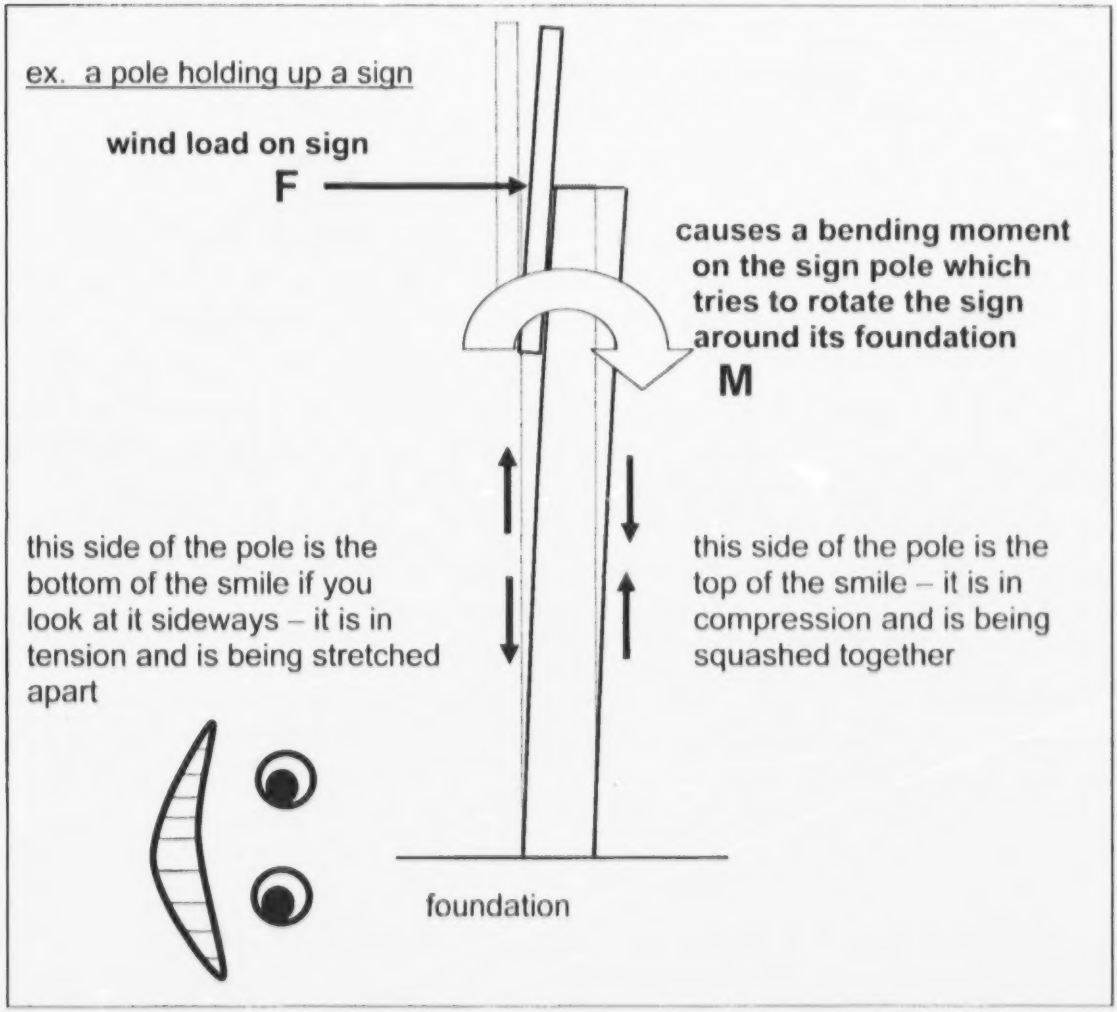
If a force (measured in Newtons) is multiplied by a distance (in meters), then units for moment are N-m (read "Newton-meters"). If force is measured in pounds and distance is given in feet, then your units will be lb-ft., read "pound-feet". The units for moments can be any force unit multiplied by any distance unit.

4) **Bending**: Bending is created when a moment or "turning force" is applied to a structural member making it **deflect (sag or arch by bending, from its original position**. A moment which causes bending is called a **bending moment. Bending actually produces tension and compression** between molecules of a structural member, causing it to "smile" – the molecules on the top of the smile get squeezed together, while the molecules on the bottom of the smile get stretched out – **a beam or pole in bending will fail in tension** (break on the side that is being pulled apart)
ex. a shelf in a book case


the top of shelf is in compression & it gets squeezed together - the molecules push back trying to stay apart
side of book case
F (weight of books)
M
M
the bottom of shelf is in tension
& it gets stretched apart - the molecules other to try pull on each to stay together
a beam is said to "smile" in bending: the top is in compression & bottom is in tension

Copyright © 2001
All Rights Reserved

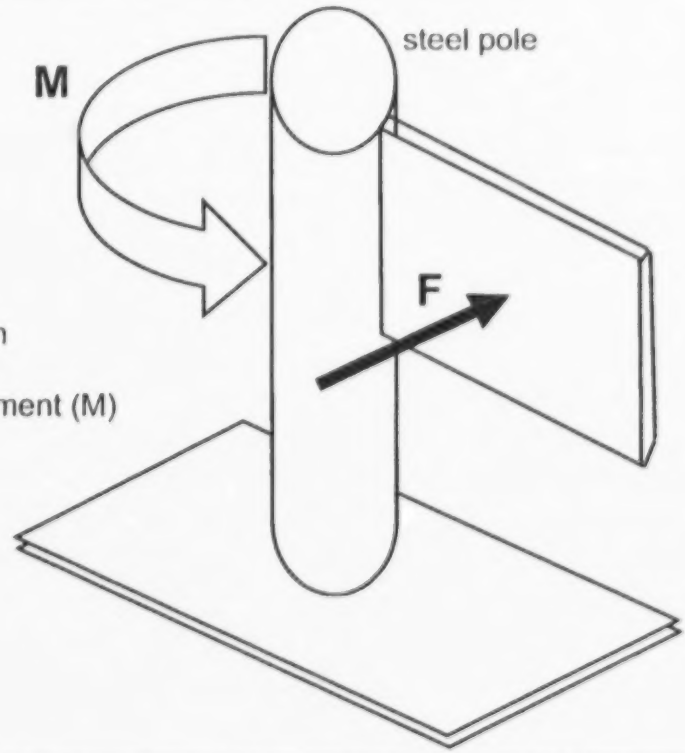
Glue stick experiment to show tension and compression created by bending. Take a glue stick used in a glue gun and use a ruler to mark four straight 4" lines which run down the length of the stick – the lines should be spaced 90 degrees apart: one on the top, one on the bottom, and one on each side of the glue stick. Hold the glue stick between a finger and your thumb, and apply a force to the middle. Notice how the lengths and shapes of the lines change. What happens to the line on the top of the glue stick (side where your finger pushes)? What happens to the line on the bottom? What happens to the lines on the two sides of the glue stick?


ex. a pole holding up a sign
wind load on sign
F
causes a bending moment on the sign pole which tries to rotate the sign around its foundation
M
this side of the pole is the bottom of the smile if you look at it sideways – it is in tension and is being stretched apart
this side of the pole is the top of the smile – it is in compression and is being squashed together
foundation

www.prek-12engineering.org
Copyright © 2001
All Rights Reserved

5) **Torsion (twisting):** Torsion is created when a moment or "turning force" is applied to a structural member (or piece of material) **making it deflect by rotating (twist)** - a moment which causes twisting is called a **twisting or torsional moment. Torsion actually produces shear stresses inside the material, between layers of molecules. A beam in torsion will fail in shear** (the twisting action causes the molecules to be slid apart sideways)

ex. a pole with a sign hanging off one side



Load (like wind) (F) acts at a distance from the center of the pole causing a twisting moment (M)

Glue stick experiment to show torsion. Again take a glue stick used in a glue gun and use a ruler to mark a series of straight lines along its length, similar to the experiment above. Hold one end of the glue stick, and get a partner to twist the other end as hard as possible. What happens to the lines on the glue stick? Imagine that each vertical line represents a line of glue molecules – **notice how they have been slid sideways out of position by the twisting moment – this is the sign of shear forces acting inside the material.**

Copyright © 2001
All Rights Reserved

PreK-12
ENGINEERING

Activity Evaluation Form

www.k12engineering.org

Activity Name: _____

Grade Level the Activity was implemented at: _____

Was this Activity effective at this grade level (if so, why, and if not, why not)?

What were the Activity's strong points?

What were its weak points?

Was the suggested Time Required sufficient (if not, which aspects of the Activity took shorter or longer than expected)?

Was the supposed Cost accurate (if not, what were some factors that contributed to either lower or higher costs)?

Do you think that the Activity sufficiently represented the listed MA Framework Standards (if not, do you have suggestions that might improve the Activity's relevance)?

Was the suggested Preparation sufficient in raising the students' initial familiarity with the Activity's topic (if not, do you have suggestions of steps that might be added here)?

If there were any attached Rubrics or Worksheets, were they effective (if not, do you have suggestions for their improvement)?

Please return to: CEEO
105 Anderson Hall
Tufts University
Medford, MA 02155

BEST COPY AVAILABLE

SE068034

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

Reproduction Release
(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: PreK-12 Engineering Activities

1) Touch and Discover, Grades PreK-2
http://www.prek-12engineering.org/data/d2/Touchdiscover.pdf

2) Invent a Backscratcher from Everyday Materials, Grades PreK-2
http://www.prek-12engineering.org/data/d28/Backscratcher.pdf

3) Compare Human-Made Objects with Natural Objects, Grades PreK-5
http://www.prek-12engineering.org/data/d34/HumanvsNatural.pdf

4) Do Different Colors Absorb Heat Better?, Grades PreK-2
http://www.prek-12engineering.org/data/d37/Absorbheat.pdf

5) Which Roof is Tops?, Grades PreK-2
http://www.prek-12engineering.org/data/d44/RoofTops.pdf

6) Make Your Own Recycled Paper, Grades PreK-2
http://www.prek-12engineering.org/data/d56/Recycle.pdf

7) Build an Approximate Scale Model of an Object Using LEGOs, Grades 3-5
http://www.prek-12engineering.org/data/d3/LegoScaleModel.pdf

8) Design Weather Instruments using Lego Sensors, Grades 3-5
http://www.prek-12engineering.org/data/d4/LegoWeather.pdf

9) Space Shelter, Grades 3-5
http://www.prek-12engineering.org/data/d5/SpaceShelter.pdf

10) Build a Bird House, Grades 3-5
http://www.prek-12engineering.org/data/d6/BirdHouse.pdf

11) Ball Bounce Experiment, Grades 3-5
http://www.prek-12engineering.org/data/d6/BallBounce.pdf

12) Make an Alarm!, Grades 3-5
http://www.prek-12engineering.org/data/d11/MakeAlarm.pdf

13) Design Packing to Safely Mail Raw Spaghetti, Grades 3-5
http://www.prek-12engineering.org/data/d17/MailSpaghetti.pdf

14) Disassemble a Click Pen, Grades 3-5
http://www.prek-12engineering.org/data/d33/clickPen.pdf

15) Construct And Test Roofs for Different Climates, Grades 3-5
http://www.prek-12engineering.org/data/d35/ClimateRoof.pdf

16) Compare Fabric Materials, Grades 3-5
http://www.prek-12engineering.org/data/d36/Fabric.pdf

17) A House is a House for Me, Grades 3-5
http://www.prek-12engineering.org/data/d52/House.pdf

18) Water Filtration, Grades 3-5
http://www.prek-12engineering.org/data/d53/Water Filtration.pdf

19) What is the Best Insulator: Air, Styrofoam, Foil, or Cotton?, Grades 3-5
http://www.prek-12engineering.org/data/d54/BestInsulator.pdf

20) Design a Recycling Game!, Grades 3-5
http://www.prek-12engineering.org/data/d55/Recycling.pdf

21) Tower Investigation and the Egg, Grades 6-8
http://www.prek-12engineering.org/data/d7/TowerEgg.pdf

22) Wimpy Radar Antenna!, Grades 6-8
http://www.prek-12engineering.org/data/d10/WimpyAntenna.pdf

23) Portable Sundial, Grades 6-8
http://www.prek-12engineering.org/data/d30/PortableSundial.pdf

24) An Introduction To Loads Acting on Structures, Grades 6-8
http://www.prek-12engineering.org/data/d31/IntroLoads.pdf

25) Design Your Own Rube Goldberg Machine, Grades 6-8
http://www.prek-12engineering.org/data/d32/RubeGoldberg.pdf

26) Building Tetrahedral Kites, Grades 6-8
http://www.prek-12engineering.org/data/d38/tetrakites.pdf

27) Do as the Romans: Construct an Aqueduct!, Grades 6-8
http://www.prek-12engineering.org/data/d39/Aqueduct.pdf

28) Build an Earthquake City!!, Grades 6-8
http://www.prek-12engineering.org/data/d40/EarthquakeCity.pdf

29) Design a Parachute, Grades 6-8
http://www.prek-12engineering.org/data/d41/Parachute.pdf

30) The Squeeze is On, Grades 6-8
http://www.prek-12engineering.org/data/d42/Squeeze.pdf

31) Stop The Stretching, Grades 6-8
http://www.prek-12engineering.org/data/d43/StopStretching.pdf

32) Speaker Project, Grades 9-10
http://www.prek-12engineering.org/data/d13/Speaker.pdf

Author(s): Erik Rushton, Emily Ryan, Charles Swift

Corporate Source: Tufts University

Publication Date:

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, Resources in Education (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.
If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign in the indicated space following.

☒ Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g. electronic) and paper copy.

☐ Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only.

☐ Check here for Level 2B release, permitting reproduction and dissemination in ERIC archival collection microfiche only.

Documents will be processed as indicated provided reproduction quality permits. If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.
I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche, or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Signature: Margaret Newell

Printed Name/Position/Title: Margaret Newell, Associate Provost for Research

Organization/Address: Tufts University
136 Harrison Avenue, Suite 75K-401
Boston, MA 02111

Telephone: 617-636-6550
Fax: 617-636-2917
E-mail Address: peter.wong@tufts.edu

Date: 8/15/2003

III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, or, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

Publisher/Distributor:
Address:
Price:

IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

Name:
Address:

V. WHERE TO SEND THIS FORM:

Send this form to:

ERIC Clearinghouse for Science, Mathematics, and Environmental Education
Acquisitions
1929 Kenny Road
Columbus, OH 43210-1080

Telephone: (614) 292-6717
Toll Free: (800) 276-0462
FAX: (614) 292-0263
e-mail: ericse@osu.edu
WWW: http://www.ericse.org

EFF-088 (Rev. 9/97)